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Cincinnati, Ohio

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IN GROUND WATER POLLUTION**

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U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
Public Health Service
Division of Water Supply and Pollution Control

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Problems in Ground Water Pollution*

Considerable publicity has been given to the increasing water needs of our expanding population and economy. Present water use in the United States has been estimated to average 300-billion gallons per day (bgd),^{1a} and the forecast of water requirements for 1980 is 600 bgd.^{2a} In these figures, single use of water is assumed; consideration has not been given to the fact that nearly two thirds of such waters are returned to surface water courses or seep into underground strata. The 300-bgd increase in water requirements forecast for 1980 may be met by recovery of used water, as well as by the development of additional water resources. In either case, ground water aquifers will play an important role.

Although only 20 percent of the 300 bgd of water currently used is obtained from the ground, these underground supplies are valuable resources. They provide 25 percent of the municipal supplies and 95 percent of the private domestic supplies.^{3a} Nearly 90 million people use domestic water supplies obtained from the ground.

In many areas ground waters are the only available supply. In some areas the use of ground water is economical because it requires a minimum of treatment and long pipe lines are unnecessary. Still other advantages of using ground water may be the uniformity of its temperature and other characteristics, and the dependability of the supply. At present more than 14 million water wells are in use in this country.⁴

Although our knowledge of underground water resources is limited, it is known that large volumes of ground water are available in some areas. The storage capacity of the aquifer beneath the High Plains area of Texas has been estimated to be five times that of Lake Meade,⁵ and the alluvial valley of the lower Mississippi River has been reported to contain sufficient ground water to supply every man, woman, and child in the United States with 190 gpd for a period of 10 years.^{6a}

* A paper prepared by Graham Walton, for presentation at the Summer Training Institute, Behavior of Pollutants in Ground Water, conducted by the Training Program, Robert A. Taft Sanitary Engineering Center, and the W. M. Keck Laboratory of Environmental Health Engineering, California Institute of Technology, Pasadena, California, August 21-25, 1961. This paper was also presented before Rural and Suburban Sewage Disposal Conference, Kellogg Center for Continuing Education, Michigan State University, January 11, 1962.

The perfection of sensitive geophysical instruments and their application to locate and determine the water yield from unknown aquifers affords opportunity, particularly in the Western States, for the discovery of extensive water resources. It has been estimated that some time within the next 20 to 50 years from one-third to one-half of the water used in this country will be drawn from the ground.^{7a} Meanwhile, it is necessary that steps be taken to protect our valuable water resources against pollution that might make them unusable.

We should examine what is known and determine what should be known about the changes that occur in quality of water as it filters through soil formations. What are the biological, chemical, and physical characteristics of water that may be injected or permitted to seep into an aquifer without causing serious deterioration in the quality of recovered water? Such information is essential not only to protect the quality of usable ground waters, but also to determine the extent that filtration through soils can be utilized for treating polluted waters.

A GROWING PROBLEM

A limited review of the occurrence of incidents of ground water pollution and the development of interest in such problems is found in the reports of the AWWA Task Group on Underground Waste Disposal and Control.⁸⁻¹¹ These compilations of information are supplied by State and Territorial Departments of Health and supplemented from other sources.

The 1952 report analyzes data received from 38 states, 2 territories, and 2 provinces. Relatively few of the states recognized any problems involving pollution of ground water. Most of the reported incidents involved bacterial contamination by sewage or chloride contamination from oil- or gas-field brines. Reports from two states mentioned that ground water pollution problems were "solved" by extension of the municipal water supply systems.

The 1953 report is essentially a policy statement. It noted, "Although ground water pollution by industrial-waste disposal is reported as relatively minor in many states, and even nonexistent in some, it is, nevertheless, nationwide in distribution."

The 1957 report is a compilation of information from questionnaires sent to the states in 1952, 1953, and 1957, supplemented by data from a U. S. Geological Survey study made during 1955. Forty-two of the 47 reporting states are shown to have experienced problems with pollution of ground water.

The 1960 report summarizes information from a questionnaire specifically requesting data on incidents observed during 1957, 1958, and 1959, plus some supplemental information that came to the attention of the Task Group. During the 3-year period covered by the 1960 report, 39 of the 48 reporting states experienced one or more incidents involving pollution of ground water.

Information in the 1957 and 1960 reports indicates that only three (Hawaii, Mississippi, and New Hampshire) states have been fortunate enough to escape problems resulting from pollution of ground water. Table 1 summarizes the data by type of pollutant and shows the number of states experiencing one or more incidents involving a particular type of pollutant. Comparison of the number of states experiencing problems with pollution of ground water during 1957-1959 with the number reporting all such experiences through 1956 shows that these problems are occurring with greater frequency. Of particular interest is the increasing occurrence of problems involving pollution by organic chemicals.

Table 1. Number of States Experiencing Incidents Involving Various Types of Pollutants of Ground Water

Pollutant source	Number of states experiencing problems	
	Through 1956 ^a	1957-1959 ^b
Sewage	28	26
Oil and gas industry and products	24	22
Chemical and industrial wastes	25	15
Other	12	13
All pollutants	42	39

^aReference 10.

^bReference 11.

CHEMICAL POLLUTION

Pollution of water has been defined as the addition, through activities of man, of substances that adversely affect the quality of water. Wastes and waste waters may pollute ground waters with chemicals present in the waste, with chemicals resulting from the reaction between substances in wastes and in soil formations, with degradation products of chemicals originally in the waste, and with chemicals synthesized from those in the original wastes. In some cases the pollutant resulting from the presence of a substance in a waste may create a more serious problem than the substance as it was originally present in the waste.

Some inorganic chemicals, such as sodium chloride, remain unchanged as they pass through the ground. Phenol, which is readily oxidized in surface waters, has been reported to have traveled 1400 feet underground in approximately 4 years and contaminated a well.¹² More resistant organic chemicals may persist for many years in a water-saturated aquifer.

SOME ILLUSTRATIVE INCIDENTS

The insidious nature of ground water pollution is illustrated by the Indian Hill incident.¹² Indian Hill is an incorporated village located about 10 miles from the Sanitary Engineering Center. The village water works, which serves about 12,000 people, obtains water from four wells drilled to a depth of about 70 feet in the alluvium in the Little Miami River Valley. The water is softened by ion-exchange filtration and disinfected.

When the softening plant was placed in operation in November 1949, brine wastes from regeneration of the filters were discharged into a small wet-weather stream tributary to the Little Miami River about one-half mile downstream from the well field.

Four years later, the water's chloride content, which had averaged 20 mg/l, rose to more than 700 mg/l. The waste brine from regeneration of the zeolite filters had seeped into the soil and traveled underground a distance of 850 feet where it contaminated the well water. Application of extensive correction measures, which would have been impossible in most cases, reduced the chloride concentration of the water to around 20 mg/l after 2 years.

There have been at least two other incidents of ground water pollution by wastes discharged from water treatment plants.

The fact that one cannot always anticipate the path of pollution travel is illustrated by the experience of a pulp mill.¹³ After careful preliminary consideration the mill disposed of its "lignin" waste by pumping it across a river into an infiltration pond 350 feet from the west bank of the river (Figure 1). It was thought that these wastes would filter through the ground and gradually seep into the river. Actually, some of the waste passed beneath the bed of the river and polluted several of the industry's own wells, located 600 feet from the east bank. The sequestering properties of the organic constituents on the waste caused the combined iron and manganese content of these well waters to increase from less than 0.1 mg/l to a concentra-

tion ranging from 4 to 20 mg/l. Use of these wells was discontinued, and intermittent pumping over a period of 5 years has not improved the quality of the water.

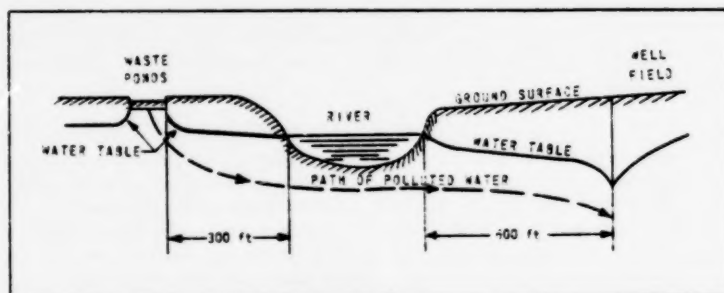


Figure 1. Diagram illustrating travel beneath river and into industrial wells

The Rocky Mountain Arsenal incident¹⁴ is one in which at least two of the polluting substances (2, 4-D and chlorates) appear to have been formed by the reactions of chemicals present in wastes discharged into the holding ponds. Although there is no evidence that 2, 4-D was ever produced at the Arsenal's facilities, it has been isolated from the holding pond and identified unequivocally by melting point, infrared spectrum, and bioassay. Apparently it resulted from the reactions of acetic acid, phenol, and chlorine, all of which were present in various waste discharges. Chlorates have been found in the polluted ground waters, and laboratory studies have demonstrated that chemicals, chlorine, and sodium hydroxide present in the wastes could react under natural conditions to form these chlorates.

The Rocky Mountain Arsenal is located northeast of Denver, Colorado. From 1943 it was operated for several years for the production of chemical warfare agents; more recently the facilities have been leased to a company manufacturing insecticides. From 1943 through September 1955, all wastes were discharged to unlined holding ponds from which they seeped underground and polluted the shallow ground waters. The first evidence of pollution was damage in 1951 to crops irrigated with shallow ground water. The area of shallow ground water pollution now (1961) extends throughout approximately 5 square miles of the South Platte River Valley. Although Public Health Service analyses of four samples of shallow ground water from this area did not detect either 2, 4-D or chlorates, the water is abnormally high in total and volatile solids, sulfates, and chlorides. It still contains a phytotoxic substance, has an obnoxious odor and taste, and is considered unsafe for human consumption.

CONTROL OF POLLUTION

The insidious nature with which the pollution of ground water occurs, the long elapsed time before it is detected, and the extended period required for it to regain its original quality make it essential to prevent pollution rather than attempt corrective measures after its occurrence.

It is the writer's opinion that relatively few of the state water pollution control agencies have adequate legal powers or personnel to prevent pollution of ground waters. The increasing frequency of incidents of pollution of ground water, particularly when 37 states consider they have adequate statutory control,¹¹ is alarming. Some actual examples of inadequacies of reportedly adequate statutory control are:

In an open meeting attended by the writer, a State's Attorney General stated that the State had no legal authority to require sealing of the upper casing of a well admitting water from both an upper polluted aquifer and a deeper unpolluted aquifer.

A Public Health Service Engineer, who attended a hearing concerned with the potential contamination of a community's water supply wells with brine wastes, reported that the Commission, although recognizing that contamination of the wells would be a matter of time, decided no action could be taken until such contamination had occurred.

A State Department of Health Engineer noted that in some of the suburban housing developments, as well as in isolated dwellings, it was the practice to discharge sewage to disposal wells. The State Department of Health had recently discovered that several well drillers operating in the state were using rigs capable of drilling disposal wells 6 feet in diameter and 100 feet deep.

If those state agencies vested with the responsibility for control of ground water pollution are to perform effectively, they must have knowledge of the fate of pollutants in water flowing through various soils, adequate legal powers, and sufficient qualified personnel to make the necessary investigations.